September 30, 1963

STATOTHR

████████████████

Itek Corporation
10 McGuire Road
Lexington, Massachusetts

Dear Geoff:

I am enclosing the summary of the research program on edge enhancement which I promised you. I did not go into too much detail because I did not feel it necessary. I believe it contains sufficient information for you to make a reasonable estimate of time and manpower necessary for its prosecution.

STATINTL

In viewing what ████████ and I did about a year ago, I feel that the same approach should be used. However, to achieve more useful results the work should be repeated, with the parameters more closely controlled.

Under the agreement we made during the conversations of September 17, I will leave it to you to decide whether you wish to pursue this investigation further. We will be content with the ████ effort as we STATOTHR discussed it, in any event. Please let us know your decision as soon as possible.

Sincerely,

STATINTL

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Enclosure:
(2 copies) - Summary for Research Program on Edge Enhancement

cc ████████████████   STATINTL

Summary for Research Program on Edge Enhancement

The purpose of the program of research for the Image Enhancement Viewer is to ascertain, once and for all, the capability of the instrument with sharp cutoff, occluding spatial filters. Collaterally, it is desired to obtain quantitatively a working definition of "image enhancement" and to study the controlling parameters. It is expected that if such a definition is produced, it will be possible to evaluate the spatial filters in terms of enhancement.

The previous efforts had not indicated a suitable criterion of image enhancement which would evolve "naturally" from the mathematical analysis or experimental results. Because of the nature of the imaging process, it was decided to use an edge model which would be capable of fitting most of the edges produced through the cascading of spread functions. A Gaussian form was found to be suitable, and since the imaging equations were Fourier Transforms, such a representation had significant mathematical tractability. It would not cover the case of adjacency effects, but this was not considered sufficient reason to seek another form.

Preliminary work showed a close fit of edges obtained through normal imagery and photographic processing. It also showed that the equations were difficult to handle because of the requisite extraction of the square root to specify amplitude variation. A squared version of the basic expression was used for analysis to facilitate integration in closed form, although the resultant curve-fit was not optimum. If a follow-up program were carried out, it would be necessary to return to the original formulation and carry out the integrations numerically. However, by treating a symmetrical image (a pulse rather than a single edge), it would not be necessary to compute the real and imaginary parts of the Transform separately, thereby simplifying the programming and interpretation.

The program following up the previous work will follow it in form, having an analytical and experimental aspect running together. The analytical program will formulate a photographic edge, or pulse, in terms of a Gaussian. This object will then be analytically passed through a coherent optical system, and filtered with high-pass, sharp cutoff, occluding filters. The resultant intensity distribution would then be examined (graphically, non-dimensionally if possible) and evaluated in light of the variables which appear significant. This should establish the relationship between non-sharp edges and occluding filters. Verifying experimentation should easily suggest itself and will not be outlined here. A useful result of such a study would be to catalog the effects of such filtering through a set of photographs (of the same object) from

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which increasing amounts of the lower spatial frequencies have been removed.

Previous study has outlined the basic opportunities for enhancement of edges; a) exposure addition of filtered and unfiltered images, and b) the multiplication of the transmission distributions of filtered and unfiltered images. The latter has the additional variability of choosing a negative or positive filtered image. These formulations were done about three years ago. Work over the past year and a half shows that they must be up-dated, and a more suitable formulation worked out. Such a formulation must naturally include the expression for the image edge, as well as the parameters defining the spatial filtering. When the various factors have been combined, the whole must be subjected to experimentation. The details of such experimentation are not obvious at this time. The problem of registration of the filtered and unfiltered images is trivial only in the case of exposure addition.

It is hoped that from the analytical expressions and consequent experimentation, a natural definition of image enhancement will evolve or might suggest itself. Certainly, unless one restricts such spatial filtering to mensuration purposes, useful enhancement must come from the combination of the filtered and unfiltered images, so that at least image tone may be preserved.

Since image enhancement is presently undefined, and its real import uncertain, an analysis utilizing the variational calculus ought to be carried out. This would attempt to specify a spatial filter which would maximize some feature of the image while holding another constant. One criterion which sounds reasonable is to require the mean-squared slope of the edge to become a maximum while holding the area under it constant. While the resultant filter shape would not likely turn out to occlude with a sharp cut off, it could provide insight into additional filter specifications and lead towards a more natural enhancement criterion. Additional considerations of phase and amplitude filter variation could be introduced when possible. In any event, since the solution of the imaging equations must employ a computer, it will require little additional work to include this sort of problem.